

Surface Cleaning and Wet Processing
Terminology
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HF FARM: Hydrofluoric Acid Filtered Acid Recirculation Module

HF is used to etch silicon dioxide (SiO_2) films on silicon (Si) wafers. The HF will etch the SiO_2 without attacking the Si surface. SiO_2 films include oxides which are thermally grown in diffusion tubes (gate oxides, field oxides); oxides which are chemically deposited (CVD = Chemical Vapor Deposition); and native oxides which grow naturally on the bare Si surface after a short period of time. HF is typically diluted with DI water in order to slow down the etch rate of SiO_2 , thereby ensuring better etch uniformity. Typical dilution ratios range from 1:1 H_2O :HF to 100:1 H_2O :HF. For certain critical etches, the HF may be diluted with ammonium fluoride (NH_4F) to promote more uniform liquid coverage on the Si surface, and it is then called a *Buffered Oxide Etch* (BOE). Since HF removes the SiO_2 , it leaves a bare Si surface when the etch is taken to completion. This bare Si surface is hydrophobic (repels water), and it is very susceptible to particle deposition. For this reason, all HF tanks are filtered continuously in the recirculation loop to remove all particles in solution. The recirculation loop also ensures that fresh HF is continually in contact with the wafer surface, which is important for uniform etching. HF FARMs are typically operated near ambient temperatures (20-25°C). Precise temperature control is required to ensure a consistent etch rate. Since HF etches quartz (a form of SiO_2), the tank is made of plastic materials.

Super Q FARM: Super Q Filtered Acid Recirculation Module

Super Q is a proprietary etchant developed by Olin Hunt. It is a precision oxide etchant that is used to remove native oxides and chemical oxides prior to metal deposition or contact formation. It contains HF and some proprietary surfactants and buffering agents, allowing it to etch doped and undoped CVD oxides at approximately the same etch rate. (Doping of chemical oxides is done during the CVD process to make the oxide “flow” better, thereby making it more conformal to the surface below). Dilute HF solutions will typically etch doped oxides 30-50 times faster than undoped oxides, while Super Q etches only five times faster. This is important for pre-metallization etches, where it is desirable to remove all oxides before depositing the conductive metal layer. Like all HF-based etchants, it results in a bare Si surface that is hydrophobic, and it is very susceptible to particle deposition. For this reason, all Super Q tanks are filtered continuously in the recirculation loop to remove all particles in solution. The recirculation loop also ensures that fresh Super Q is continually in contact with the wafer surface, which is important for uniform etching. Super Q FARMs are typically operated near ambient temperature (20-25 °C). Precise temperature control is required to ensure consistent etch rate.

Nitride Etch Tank

Phosphoric acid (H_3PO_4) is used to etch silicon nitride (Si_3N_4) films from the Si surface. Silicon nitride films are chemically deposited (CVD) on the Si surface at several steps in the wafer fabrication process. Phosphoric acid is used to etch the Si_3N_4 from the surface without attacking the Si or the SiO_2 . Phosphoric acid tanks are typically operated at very high temperatures of 140-180 C, and precise temperature control is required to maintain consistent etch rates. They can be configured as static tanks or recirculated tanks, although static is the most common configuration. In most applications, the nitride etch is not a very critical step in the overall process, and it is not necessary to use a filtered recirculation loop. Since evaporation occurs quickly at the high temperatures of operation, DI water is typically injected to maintain constant concentration and volume. Condensing coils are also utilized above the tank to keep evaporation to a minimum. Due to the high temperature of operation, the tank is made of quartz. Sometimes the term “sinrem” is used to describe the nitride etch process (sinrem is short for Si_3N_4 removal).

Piranha Recirculation Tank

Piranha is a trade name for a chemical mixture consisting of sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2). It is typically mixed in concentration ratios of around 4:1 $\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2$. There are two main applications for piranha in wafer fabrication: 1) it is used to remove organic contaminants from the surface of the wafer during cleaning sequences; and 2) it is used to strip photoresist from the surface of the wafer. (Photoresist is an optical coating analogous to camera film, which is used to develop the patterns on the wafer that ultimately result in the electronic device architecture). Piranha tanks feature a filtered recirculation loop to ensure that fresh solution is continuously delivered to the wafer surface. This is especially important in removing photoresist films. Piranha solutions are typically operated at high temperatures of 120-140 °C, necessitating the use of quartz tanks and precise temperature control. At these temperatures, the H_2O_2 decomposes very quickly, and “spiking” or injection of fresh H_2O_2 is usually performed.

SC-1 Recirculation Tank: Standard Clean #1

SC-1 is an abbreviation for Standard Clean Soution #1. Its name is derived from the original wafer cleaning process developed at RCA Laboratories in 1970. This clean consists of a sequence of cleaning steps using “standard” solutions which has become known as the “RCA clean”. Standard Cleaning solution #1 consists of a mixture of ammonium hydroxide (NH_4OH), hydrogen peroxide (H_2O_2), and DI water (H_2O). A typical concentration ratio for the mix is 1:1:5 $\text{NH}_4\text{OH}:\text{H}_2\text{O}_2:\text{H}_2\text{O}$, although recently ratios as low as 0.05:1:5 have been used for better cleaning performance. The SC-1

solution is the best known treatment for removing particles from the surface of the wafer. The SC-1 solution is also very effective at removing organic contaminants and some metallic contaminants from the surface of the wafer. It accomplishes this by continually oxidizing and then etching the surface of the wafer, thereby dissolving the contaminants into solution. It is typically operated in the temperature range of 50-70 °C, and plastic tanks with a filtered recirculation loop are utilized to remove particles from solution. Frequently, megasonics is used to enhance the cleaning efficiency of the SC-1 process, in which case it is called a *SC-1 Meg Tank*. (Megasonics refers to a transducer mounted in the bottom of the tank that generates high power acoustic energy waves. This additional energy aids in removing particles from the wafer surface).

SC-2 Recirculation Tank: Standard Clean #2

SC-2 is an abbreviation for Standard Clean Solution #2. Its name is also derived from the original wafer cleaning process developed by RCA Laboratories, and it is part of what has become known as the "RCA clean". Standard Cleaning solution #2 consists of a mixture of hydrochloric acid (HCl), hydrogen peroxide (H₂O₂), and DI water (H₂O). A typical concentration ratio for the mix is 1:1:5 HCl:H₂O₂:H₂O. The SC-2 solution is best for removing metal contaminants from the wafer surface, and it usually follows the SC-1 in the RCA sequence. Like the SC-1, it removes metals by continually oxidizing and then etching the surface of the wafer, thereby dissolving the contaminants into solution. It is typically operated in the temperature range of 50-70 °C, and plastic tanks with a filtered recirculation loop are utilized to remove particles from solution. Occasionally, megasonics is used to enhance the particle removal efficiency of the SC-2 process, in which case it is called a *SC-2 Meg Tank*.

Solvent Tanks

Solvent tanks may contain any one of a number of organic solvents. Typical examples might include NMP (n-methyl pyrrolidone), methanol, isopropyl alcohol, NOW, ST-22, PSR, etc. Although the applications of each solvent are high specific, the majority are used to remove photoresist and/or photoresist polymers that form during high energy processing such as ion implantation or dry plasma etching. These processes change the surface chemistry of the photoresist (and possibly the underlying layers), making them difficult to remove with conventional piranha strips. In addition, some solvents are used to remove the complex metal silicides and polymers which form when the conductive metallizations reacts with other layers in the chip, particularly during high energy processes such as plasma etching. These photoresist and metal residues can severely impact yield, so considerable attention is given to solvent processing to ensure complete removal. Since most organic solvents will attack plastic materials, solvent baths are almost exclusively made of high grade stainless steel. Solvent tanks may be configured either in a recirculation mode or as a static tank, depending on the importance of the particle filtration and fluid dynamics. Most solvents are operated at elevated temperatures to enhance the surface chemical reactions.

OFR Tank: Overflow Rinse Tank

The overflow final rinse tank is used to remove residues from the wafer surface after chemical processing. Upon extraction from the chemical process tank, the wafers are immediately placed in the OFR tank for rinsing. The term “overflow” describes the flow action in the tank: DI water enters at the bottom, flows up and over the wafers, and then over the weir to the drain. The rinse process time generally ranges from two to 10 minutes, depending on the prior wafer history. A resistivity probe can also be used to monitor the chemical concentration in the bath, thereby determining when the rinse process is complete (called “rinse to resistivity”). The tank material is usually plastic, although quartz is sometimes used. The DI water is usually at ambient temperature, although in some applications (e.g., after a piranha process), hot DI water may be used at temperatures from 60-85 °C. In this case, the tank is called a *Hot OFR Tank*. In addition, megasonics transducers may be incorporated into the rinse tank to enhance the removal of chemical residues from the wafer surface, in which case it is called a *Hot OFR Meg Tank*.

QDR Tank: Quick Dump Rinse Tank

The quick dump rinse tank is used to remove residues from the wafer surface after chemical processing. Upon extraction from the chemical process tank, the wafers are immediately placed in the QDR tank for rinsing. The term “quick dump” describes the rinse technique used. The tank is filled with DI water and overflowed (similar to the OFR) for a short period of time (typically 30 seconds to one minute). Next a door at the bottom of the tank is opened, and the tank is drained almost instantaneously. Finally, the tank is refilled with DI and the cycle is repeated, typically four to six times. The advantage of the QDR tank is that it helps to remove viscous chemical residues on the wafer surface by introducing shear stresses during the dump phase of the cycle. The tank material is usually plastic, although quartz is sometimes used. The DI water is usually at ambient temperature, but in some applications (e.g., after a piranha process), hot DI water may be used at temperatures from 60-85 °C. In this case, the tank is called a *Hot QDR Tank*. In addition, megasonics transducers may be incorporated into the rinse tank to enhance the removal of chemical residues from the wafer surface, in which case it is called a *Hot QDR Meg Tank*.

Final Rinse Tank

The final rinse tank is used after the initial OFR or QDR rinse process. It is intended to remove any residual chemicals or particles that may have been left after the intermediate rinse process. Its configuration is identical to that of the OFR tank, and it is fabricated from either quartz or plastic.

IPA VJD: Isopropyl Alcohol Vapor Jet Dryer

The IPA VJD is used to dry the wafers after the rinse process. The VJD generates a vapor cloud of isopropyl alcohol that displaces water from the surface of the wafer. The IPA/water mixture that collects at the bottom of the chamber is aspirated from the tank, and heated nitrogen is then introduced to evaporate the remaining IPA. The dryer utilizes a sealed stainless steel process chamber heated to maintain precise control of the IPA condensation on the wafer surface. The sealed chamber also prevents the escape of any alcohol fumes.

SRD: Spin Rinse Dryer

The SRD is also used to dry the wafers after the rinse process. The SRD utilizes centrifugal force to remove water from the wafer surface. Wafers are placed in the spin chamber, which may sometimes incorporate an additional rinse cycle, and are then spun at very high rpm to sheet water off of the surface.